PREDICTION OF CONCRETE MIX PROPORTION DATA FOR REQUIRED COMPRESSIVE STRENGTH AND WORKABILITY USING EXISTING LABORATORY DATA

Tanmay Kalola[1], Dr. Ketan L Timani[2]

[1]PG Student Department of Structural Engineering, L. J. Institute of Engineering & Technology, Gujarat, India
[2]Associate Professor, Applied Mechanics Department, Vishwakarma Government Engineering College, Gujarat, India

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Abstract - *Concrete mix design is performed in laboratory based on some empirical equations and the experience of the mix designer. To arrive at the required mix proportion a number of trial mixes are prepared and tested to authenticate various design parameters which is very time taking process. The aim of my work is to design a system which will reduce the number of trials required to reach the required concrete mix design. Today is an era of data, with the help of past concrete mix design data and applying suitable numerical modelling technique we will try to model a system which will accept the input as the concrete compressive strength and workability and would display output as the predicted concrete mix proportions like coarse aggregate content, fine aggregate content, cement level, w/c ratio. After the system has been modelled we will validate the system by conducting actual mix design based on the predicted mix proportions. At the end we will try to establish that the compressive strength and workability actually obtained meet the values for which we predicted the concrete mix proportions..*

Key Words*: *Concrete, Regression analysis, Multiple linear regression, Cement, Compressive, Workability.

1. INTRODUCTION

Concrete is the most used construction material throughout the world. It is used second most after water on planet earth. It is made by intermixing cementious material, water, aggregates and admixture in required proportion. When we place the resulting mixture in formwork and is cured properly then it hardens into rock-like mass called concrete. The hardening process happens due to reaction between cement and water and this reaction continues for a long period of time and consequently concrete gets hardened with age. The strength, durability and workability of concrete mix depends upon the physical and chemical properties of concrete mix, their proportions ,the method of compaction, quality control during placing concrete. Concrete is popular because we can change the mix proportion of ingredients to tailor our needs. The aim of research paper is to make a statistical model using Multiple Linear regression analysis that would predict the concrete mix proportions for 1 cubic metre of concrete like cement level, water level, fine aggregate level and admixture percentage as per cement level for desired target compressive strength of concrete and desired workability of concrete.

2. BACKGROUND LITERATURE

According to previous study of Deepansh Sharma, Gulsimar Kaur, Himanshu Arora, Ishan sharma, Jyoti Diwakar, Muskan Jain reviews various regression analysis methods and their application in machine learning. The authors also described the application of regression methods in Business optimization[1].

Dr K.L Timani and Dr. R.K Jain studied the influence of clay percentage, dry density, moisture content, cohesion and angle of friction on CBR values. The author prepared clay-sand-gravel mixture by mixing clay to sand in percentage varying from 10 to 50 percentage and performed CBR test, triaxial test by adopting density and moisture content values obtained from heavy compaction test. The author performed multiple linear regression analysis to estimate clay-sand gravel mixture's CBR value under unsoaked conditions. CBR value was treated as dependent variable and clay percentage, dry density, moisture content, cohesion and angle of friction were considered as independent variables. The resulting statistical model had an excellent coefficient of determination value = 0.95 and standard error of 0.051.The F-value test was also conducted to find the significance of all multiple regression coefficients and it was found out to be 205.24 which was higher than the critical F-value of 2.84 for α = 0.05.This shows that the multiple regression coefficients of whole model has strong correlation with CBR value. Also the author conducted t-value test on the multiple linear regression coefficients to test their significance. The t-value of each multiple linear regression coefficient was higher than the critical t-value which shows all multiple linear regression coefficients are significant correlation with CBR values. The t-statistic test value along with the p-values are shown below in table. [2].

	Coefficients	Standard error	t-value	p-value	t-critical
Intercept	2.28	0.13	16.73	0.0033	2.021
Clay(%)	-0.43	0.19	-2.29	0.0028	
Moisture content(%)	-0.26	0.09	-2.81	0.0076	
Cohesion	0.23	0.1	2.27	0.0285	
Angle of friction	1.25	0.1	11.92	0.0000	

Table 2.1 Multiple linear regression coefficient table

Palika chopra, Rajendra kumar Sharma and Maneek kumar performed mathematical analysis using statistical methods, for prediction of compressive strength of concrete based on concrete strength data obtained from experimental work conducted under standard conditions in the laboratory. The variables used in the prediction models were the mix proportioning elements, which include water-cement ratio, aggregates to cement ratio and multiple regression models were developed to predict the compressive strength of concrete [4].

Sourav Das,P. Pal and R.M Singh tried to predict the concrete mix proportion of M-25 grade concrete like cement level, water level, coarse aggregate level, fine aggregate level using Artificial Neural Network method.The author has also compared the results obtained by Artificial Neural Network with regression method. The author has used indices like root mean square error, coefficient of correlation and model efficiency to compare both model [5].

Santosh R, Dr. P Shivananda has compared water-cement ratio, water content, cement content, fine aggregate and coarse aggregate content for M-15, M30 and M-45 grades obtained by Indian standard method IS 10262: 2009, American concrete institute ACI 211.1-1991 and British standards BS 8500-1:2006.IS method gave lowest water-cement ratio, water level, highesh cement level, fine aggregate content for above mentioned grade of concrete[6].

3. Mutliple Linear Regression Analysis

Multiple Linear regression analysis is a statistical method which predicts the value for dependent variable by taking inputs from multiple independent variables. The main output of this method are the regression coefficients of independent variables whose values are such that the magnitude of random error is minimized.We conduct F-value test to confirm the significance of whole model and t-value test to confirm the significance of individual variables on dependent variable.We use Coefficient of Determination and Standard error to check the efficiency of multiple regression model.

3.1 Presentation of Data

In this research paper we presented my theoretical statistical model and the results of trial mix design that we performed as per proportions predicted by the statistical model for M-20, M-25 and M-30 grade concrete.The sample data comprises of past mix design that were performed in a NABL accredited private laboratory as per IS 456 and IS 10262.Data was selected for those concrete mix designs that were performed by using OPC-53 grade cement and zone of sand was I, II and III. The data collected was the proportions of various ingredients like cement level, water level, coarse aggregate level, fine aggregate level, admixture percentage as per cement level for producing 1 cubic metre of concrete,fineness modulus of fine aggregates used and fineness modulus of coarse aggregates used.Suitable admixture was also used to achieve high degree of workability in these past mix design. In this study, 48 past mix designs for M-20 grade was taken for very-low to very-high workability ranging from 0 mm slump value to 150 mm slump value.Also in this study, 65 past mix designs for M-25 grade was taken for very low to very high workability ranging from 5 mm slump value to 140 mm slump value.Also in this study,43 past mix designs for M-30 grade was taken for very low to very high workability ranging from 5 mm slump to 150 mm slump value.For predicting the dependent variables like cement level, water level, fine aggregate level in kg for 1 cubic metre of concrete we employed independent variables like fineness modulus of fine aggregate, fineness modulus of coarse aggregate, slump value and compressive strength of concrete.All collected data has graded coarse aggregate of maximum 20 mm size. The coarse aggregate content was founded out by subtracting the volume proportion of above stated entities from 1 cubic metre. For this appropriate value of specific gravities for cement, water, fine aggregate, coarse aggregate was assumed as 3.15,1,2.86,2.88.The results of the theoretical model are stated as under. The analysis was carried on PHstat software by pearson in MS excel.

3.2 MLR model for M-20 concrete

On Performing MLR analysis on 48 past mix designs of M-20 grade concrete we obtained below stated equation to predict concrete mix ingredients for 1 cubic metre concrete.

Cement level (kg/m3) = -788.2813+161.3064*(FMFA) + 437.2226*(FMCA)+0.0067*(S)+0.3401*(C)

Water level (kg/m3) = -293.2749 + 89.5097*(FMFA) + 210.7473*(FMCA) + 0.0073*(S) – 3.4685*(C)
Fine aggregate level (kg/m3) = 1605.3715 – 147.1027*(FMFA) – 354.0211*(FMCA) – 0.0386*(S) + 3.4832*(C)
Admixture content (in %) = 2.4676 – 0.0085*(W) – 0.4511*(FMFA) + 0.0097*(S)

S = required slump value in mm
C = required compressive strength in N/mm^2
FM_{FA} = Fineness modulus of Fine Aggregate
FM_{CA}= Fineness modulus of Coarse Aggregate
W = Water level in kg/m3 predicted by model

Regression statistics	Cement level	Water level	Fine aggregate level	Admixture percent
R-square	0.9826	0.976	0.981	0.9339
Standard error	3.0054	1.7055	2.6019	0.0832
F-value	608.1095	437.1875	553.6808	207.0626
p-value of F-value	0	0	0	0

Table 3.1 Regression stats for M-20 concrete MLR model

3.2 MLR model for M-25 concrete

On Performing MLR analysis on 65 past mix designs of M-25 grade concrete we obtained below stated equation to predict concrete mix ingredients for 1 cubic metre concrete.

Cement level (kg/m3) = = -2007.5059 + 35.2567*(FMFA) + 1288.8898*(FMCA) + 0.0154*(S) + 9.0781*(C)
Water level (kg/m3) = -1002.8844 + 1.9363*(FMFA) + 750.8351*(FMCA) + 0.0116*(S) + 0.7201*(C)
Fine aggregate level (kg/m3) = = 2717.7099 – 15.8053*(FMFA) – 1172.4726*(FMCA) – 0.0564*(S) – 3.9391*(C)
Admixture content (in %) = 2.54196 – 0.0218*(W) + 2.3706*(FMFA) + 0.0101*(S)

S = required slump value in mm
C = required compressive strength in N/mm^2
FM_{FA} = Fineness modulus of Fine Aggregate
FM_{CA}= Fineness modulus of Coarse Aggregate
W = Water level in kg/m3 predicted by model

Regression statistics	Cement level	Water level	Fine aggregate level	Admixture percent
R-square	0.9792	0.9568	0.9713	0.9475
Standard error	3.6411	2.07	3.2842	0.09
F-value	705.155	332.3784	507.914	366.8771
p-value of F-value	0	0	0	0

Table 3.2 Regression stats for M-25 concrete MLR model

3.3 MLR model for M-30 concrete

On Performing MLR analysis on 43 past mix designs of M-30 grade concrete we obtained below stated equation to predict concrete mix ingredients for 1 cubic metre concrete.

Cement level (kg/m3) = 498.1858 + 252.0712*(FMFA) + 121.6494*(FMCA) + 0.0001*(S) +1.4692 1.4692*(C)
Water level (kg/m3) = 474.1721 – 4.5290*(FMFA) + 435.4071*(FMCA) - 0.0007*(S) – 0.0325*(C)
Fine aggregate level (kg/m3) = 1700.7576 – 80.5561*(FMFA) – 482.4116*(FMCA) + 0.0421*(S) + 0.5140*(C)
Admixture content (in %) = 1.5611 – 0.0113*(W) + 0.1452*(FMFA) + 0.0104*(S)

S = required slump value in mm
C = required compressive strength in N/mm^2
FM_{FA} = Fineness modulus of Fine Aggregate
FM_{CA}= Fineness modulus of Coarse Aggregate
W = Water level in kg/m3 predicted by model

Regression statistics	Cement level	Water level	Fine aggregate level	Admixture percent
R-square	0.9883	0.9913	0.9955	0.9443
Standard error	1.7425	0.636	0.863	0.1109
F-value	799.8957	1087.2693	2111.2671	220.3836
p-value of F-value	0	0	0	0

Table 3.1 Regression stats for M-30 concrete MLR model

4. Experimental Study

In order to validate the MLR model for M-20, M-25 and M-30 grade concrete, we casted 9 cubes X 5 = 45 for desired slump value and target compressive strength based on the values predicted by MLR model for each concrete grade. A total 135 cubes were casted. We measured the slump value as per IS 1199 in fresh state after casting and after curing for 28 days we find its compressive strength as per IS 516.After obtaining the slump value and compressive strength we calculated the percentage error between the desired values and obtained values of compressive strength and slump value. The cement used for trial mix was OPC-53 grade Kamal cement. The graded coarse aggregate of maximum size of 20 mm were used and its source is Sayla near Surendranagar. The source of fine aggregate is Limbdi Bhogavo river. In order to get varying value of FM for sand we added respective size fraction material from same sand. The F.M of sand varied between 2.78-2.85.The results obtained are tabulated below.

Trial No.	Desired strength (N/mm2)	Desired Slump(mm)	Obtained strength (N/mm2)	Obtained Slump (mm)
1	26.7	40	27.1	45
2	26.8	60	27.6	60
3	28.7	90	28.2	95
4	29.8	130	28.7	125
5	29.6	150	28.9	150

Table 4.1 Desired and Obtained values for M-20 concrete

Desired strength (N/mm2)	Desired Slump(mm)	Obtained strength (N/mm2)	Obtained Slump (mm)
33.4	30	34.6	35
34.0	45	34.3	45
32.8	90	35.7	95
35.0	110	36.1	120
37.0	130	38.6	135

Table 4.2 Desired and Obtained values for M-25 concrete

Desired strength (N/mm2)	Desired Slump(mm)	Obtained strength (N/mm2)	Obtained Slump (mm)
39.8	25	40.3	25
40.0	75	41.3	80
41.0	100	42.7	110
39.0	120	39.7	115
41.0	150	41.9	145

Table 4.3 Desired and Obtained values for M-30 concrete

Trial number	Percentage error in compressive strength	Percentage error in slump value
1	+1.49%	+12.5%
2	+2.98%	0%
3	-1.74%	+5.55%
4	-3.69%	-3.85%
5	-2.36%	0%

Table 4.4 Percentage error in strength and slump values for M-20 concrete

Trial number	Percentage error in compressive strength	Percentage error in slump value
1	+3.59%	+16.67%
2	+0.88%	0%
3	+8.84%	+5.55%
4	+3.14%	+9.09%
5	+4.32%	+3.538%

Table 4.5 Percentage error in strength and slump values for M-25 concrete

Trial number	Percentage error in compressive strength	Percentage error in slump value
1	+1.25%	0%
2	+3.25%	+6.67%
3	+4.14%	+10%
4	+1.79%	-4.17%
5	+2.19%	-3.33%

Table 4.6 Percentage error in strength and slump values for M-30 concrete

The '+' sign indicates that we are obtaining higher values of compressive strength or slump than the desired values and '-' sign indicates we are obtaining lesser values of compressive strength or slump than desired values. Also this variation can be explained graphically. The following two graphs shows plots between desired values on x-axis and obtained values on y-axis. Those points that lie above equal area axis denoted by black line have higher values than the desired values and those that lie below have lower values than the desired values.

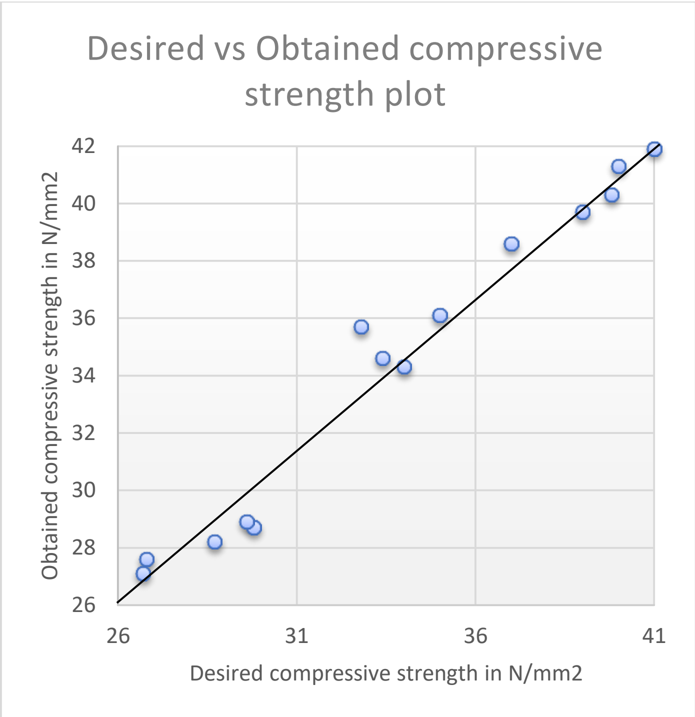

Figure 4.1 Desired vs Obtained compressive strength plot

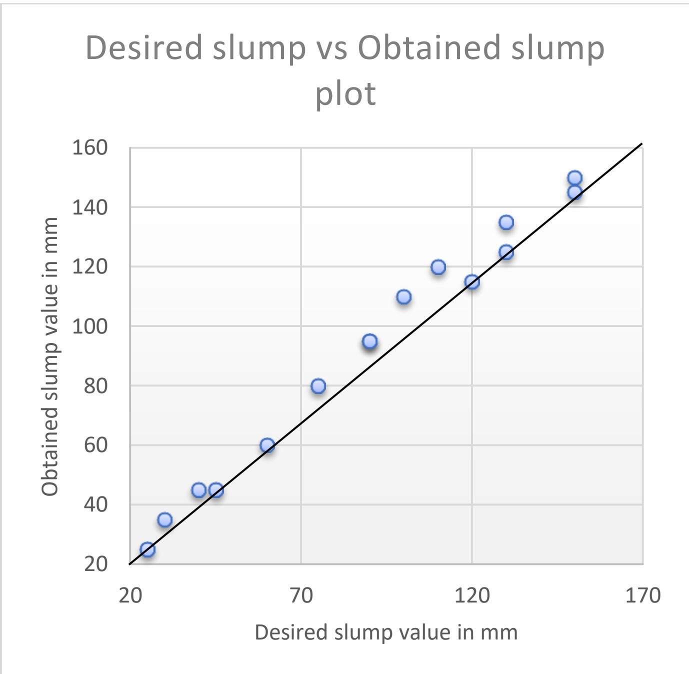

Figure 4.2 Desired vs Obtained slump plot

5. CONCLUSIONS

- The theoretical multiple linear regression model to predict concrete mix proportions of M-20, M-25 and M-30 has highest coefficient of determination value of 99.55% and lowest value of 93.39%
- The maximum value of standard error for multiple linear regression model to predict concrete mix proportions of M-20, M-25 and M-30 is 3.6411 and lowest value of 0.0832
- The maximum percentage error in predicted values and observed values of compressive strength and slump value for M-20 grade concrete is -3.69% and +12.5% respectively.
- The maximum percenatage error in predicted values and observed values of compressive strength and slump values for M-25 grade concrete is +8.84% and +16.67% respectively.
- The maximum percenatage error in predicted values and observed values of compressive strength and slump values for M-30 grade concrete is +4.14% and +40% respectively.

6. REFERENCES

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